Innovative Structural Slab Practices – Voided Slabs

Session sponsored by ACI/ASCE 421

Mike Mota Ph.D., P.E., F.ASCE
CRSI - Atlantic Region Manager
Session Moderator

April 14, 2013
Minneapolis, MN
Agenda

• Historical Overview
• CRSI Design Guide for Voided-Slabs
• New Trends – Case Studies
  – Miami Art Museum
  – UW LaBahn Arena
  – Harvey Mudd College
Historical Overview
Tests of RC Hollow Tile
(Purdue U.- Oct. 1907)

Source: W. K. Hatt
Material Properties

- Tension in steel – 16,000 psi
- Concrete f’ c – 750 psi
- Shear in Concrete – 75 psi
  - One-way shear $2 \sqrt{f’ c} = 55$ psi
Loading the slab
Load Test Results

- Slab designed for 100 psf (LL)
- Maximum LL
  - 510 psf at yield
  - 710 psf at end of test
- Max. Deflection
  - 3” deflection caused slab to bottom out ~ L/75
Purdue University - Oct. 1907
Use of Cores in RC Floors

Source: Concrete-Cement Age: August 1914
(two-way) slab - 1915

Structure Magazine (2008)
Ida B. Wells Housing (Chicago)

Source: Journal of ACI (Nov, 1941)
Ida B. Wells Housing (Chicago)

- 124 Buildings
- 3,000 tons of rebar
- 46,000 cy of concrete

Journal of ACI (Nov, 1941)
Journal of ACI (Nov, 1941)
Voided Flat Plate Slabs Reduce Cost and Speed Up Construction

by H. J. Bonet and Bill Williams, Jr.

This article describes an unbiased approach utilized to select the best concrete construction system for an operations center building. The concrete voided flat plate slab system was selected as the most appropriate system for the structure. It is shown how the final design was made.

A brief description of the conditions incorporated in the actual construction and how they were developed is also explained. The completion of the concrete structure ahead of schedule and below the estimated cost proved all the predictions and affected the planning of all the objectives.

Keywords: computer programs; concrete construction; post-earthquake resistant structures; flat concrete platoes; flat concrete slabs; fly ash; framing systems; hollow core slabs; moments; office buildings; reinforced concrete; structural design.
688,000 sq. ft. “Low-rise”
40 feet Unobstructed Spans
Heavy LL (125 PSF)
Cost (sq. ft.) Comparison
Anchoring The Voids

- Type A or B rebar chair
- Void spacing to be determined
- Top rebar
- Top of slab
- 18" slab
- 4"
- 10" diameter sonotube void form
- Snap tie hold down assembly (rolled to match void diameter)
- Bottom rebar
- Bottom rebar chair
- Plywood deck
- Wedge plate
- Void chair
Anchoring The Voids
Flat Terra Cotta Arch
Slag Block

TYPICAL CONSTRUCTION
Wide-Module Joists
Waffle Slabs
Hollow Core Plank
Foam voided Systems
Questions?
CRSI Design Guidelines
Voided Slabs

Attila Beres Ph.D., P.E.
CRSI – Senior Structural Engineering Consultant

Session sponsored by ACI 421
Motivation

To provide guidance to design professionals to introduce an innovative and unconventional system

Associated CRSI publications geared towards contractors:
• Articles in trade publications
• Sample specifications, general notes, typical details etc.
Current Innovation in Void-former Creation

Crate type voids

Tubes  Plastic Balls
Reviewers/Collaborators

Purveyors of Systems/Designers

- Michael Russillo, Christian Roggenbuck (Cobiax)
- Jerry Ames Clark, Dan Windorski (BubbleDeck/Graef)
- Ricardo Levinton, Ron Klemencic (Prenova/MKA)

Contractors

- Rocky Bowe (Titan Builders),
- Elan Hertzberg, Dan Stafford (Matt Construction)
Significant Projects Around the World

Millenium Tower
Rotterdam, Netherlands

Airport
Yerevan, Armenia

Palazzo Lombardia
Milan, Italy
Content of Guidelines

• Introduction of Voided Slab Concept
• Historical Overview
• Construction Issues
• Design Regulations
• Design Tools (Tables and Charts)
• Featured Projects
• References
Construction Methods

Why to address constructability in a “Design Guideline”? 

- The design means and methods make this system unique 
- GCs and Subcontractors are viewing any new systems with skepticism – Who is taking the risk? 
- Constructability issues essential to understand to develop design 
- For any novel systems the designer is “promoting” the system
Construction Methods

Understanding building methodology:

- Securing void formers against buoyancy
- Sequencing/placement of rebar, void formers, and concrete
Construction Methods

Understanding implications of procedures:

• Shoring, Forming
• Placement of rebar, void formers, and concrete

Where are the $s?
Construction Methods

Addressing constructability concerns:

• Are there any concrete consolidation issues?
• Is there any concern with the interface of 2 concrete lifts?
• Resiliency of void formers at the construction site (handling+ building site foot traffic)?
• Field repositioning
• Time to completion
Construction Methods

Detailing concerns:

• Post-installed anchors
• Intentional drilling into void formers
• Transition between voided areas and solid zones
• Interconnectivity of precast components
• Accommodation of electrical, mechanical, PT conduits
Construction Methods

Administrative implications:

- Placement/shop drawings
- Specifications
- Inspection issues
Design Regulations

Code Compliance:
- ACI 318
- Other IBC Requirements (fire)
Design Regulations

Compliance with non-mandatory considerations:

• Sustainability
• Vibration
• Sound insulation
• Thermal
Design Concepts and Issues

Steps of the Design Procedure:
1. Defining the computational model and parameters
2. Establish adjustment factors specific to the voided slab system
3. Creation of negative dead load patterns
4. Perform initial analysis
5. Shear analysis to establish solid zones
6. Refine iterations
7. Flexural design
Parameters Used in Structural Analyses and Design:

- Stiffness
- Flexural strength
- Shear capacity
- Punching shear
Example of Weight Reduction:
(shorter span and light load)

- 10” thick slab
- 5.5” tall x 12 3/8” wide void former
- 1 3/8” spacing
- 0.25 ft³/ft² concrete eliminated
- Self weight reduction from 125 psf to 88 psf -30%
Design Concepts and Issues

Example of Weight Reduction:
(longer span and heavy load)

• 21” thick slab
• 16” wide spherical void former
• 1 3/4” spacing
• 0.56 ft³/ft² concrete eliminated
• Self weight reduction from 269 psf to 185 psf -31%
Design Concepts and Issues

Other Engineering Design Considerations:

- Diaphragm performance (in plane shear and flexure)
- Design models (similitude with equivalent 2–way solid slabs, 2-way joists)
- Deflection considerations
- Crack-width considerations
Design Concepts and Issues

Detailing issues:

• Layout in typical scenarios
• Layout for complex geometries (non-rectilinear floorplan, upturn beams, steps, openings/edge conditions
Design Tools

◆ Preliminary sizing - RC Concept
◆ Samples of Design Documents:
  • General Notes
  • Typical Details
  • Floor Plan Layouts
  • Specifications
RC Concept

VOEDED SLAB
Economically viable for medium to long spans and for moderate live loads.

**Economical Span Range (ft)**
- Typical slab depths vary from 14" to 24"
- Typical spherical void-former diameter varies from 9" to 18"

**Advantages**
- Larger spans without beams
- Larger open floor areas
- Lower floor to floor heights
- Improved Earthquake Performance
- Resource efficiency

**Placeholder for cost calculations**
- Placing: $0.00 /yd³
- Finishing: $0.00 /ft²
- Curbing: $0.00 /ft²

**Reinforcing in Place**
- Rebar: $0.00 /ton
- Voids in Place: $0.00 /ft³
- Forms in Place: Edge forms: $0.00 /ft²
  - Beam forms: $0.00 /ft² contact area

**Consult manufacturers for the cost of voids in place.**
**Edge forms unit cost is applicable in all systems.**

**Click to Close**
## RC Concept

### Voided Slab

**CLICK FOR MORE INFO**

<table>
<thead>
<tr>
<th><strong>Loads</strong></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Superimposed dead loads:</td>
<td>20 psf</td>
</tr>
<tr>
<td>Live loads:</td>
<td>100 psf</td>
</tr>
</tbody>
</table>

**Notes**
- Superimposed dead loads include topping slabs, floor finishes, and HVAC.
- See IBC Table 1607.1 or ASCE/SEI Table 4-1 for minimum uniformly distributed loads for various occupancies.

<table>
<thead>
<tr>
<th><strong>Material Properties</strong></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Concrete compressive strength $f'_c$:</td>
<td>4,600 psf</td>
</tr>
<tr>
<td>Concrete unit weight $w_c$:</td>
<td>150 psf (normal)</td>
</tr>
<tr>
<td>Reinforcing steel yield strength $f_y$:</td>
<td>60,000 psi</td>
</tr>
</tbody>
</table>

**Notes**
- For typical cases, 3,000 - 5,000 psi concrete is the most economical for floor systems.
- Enter 110 or 120 psf for lightweight concrete; 150 psf for normal weight concrete.
- Grade 60 (fy = 60 ksi) reinforcement is the most commonly used for floor systems.

<table>
<thead>
<tr>
<th><strong>IN-PLACE UNIT COSTS</strong></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Concrete</strong></td>
<td></td>
</tr>
<tr>
<td>Material:</td>
<td>$1.00/yd^3$</td>
</tr>
<tr>
<td>Placing:</td>
<td>$1.00/yd^3$</td>
</tr>
<tr>
<td>Finishing:</td>
<td>$1.00/yd^3$</td>
</tr>
<tr>
<td>T-curing:</td>
<td>$0.5$</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th><strong>Reinforcing In Place:</strong></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Rebar:</td>
<td>$1.00/ton$</td>
</tr>
<tr>
<td>Voids In Place:</td>
<td>$1.00/ft^2$</td>
</tr>
<tr>
<td>Forms In Place:</td>
<td></td>
</tr>
<tr>
<td>Edge forms:</td>
<td>$1.00/ft^2$</td>
</tr>
<tr>
<td>Beam forms:</td>
<td>$1.00/ft^2$ contact area</td>
</tr>
</tbody>
</table>

**Notes**
- In-place unit costs can be obtained from numerous references, including RS Means or can be obtained from local concrete contractors.
- Consult manufacturers for the cost of voids in place.
- Edge forms unit cost is applicable in all systems.
RC Concept

### VOIED SLAB

**Columns (In. x In.)**

<table>
<thead>
<tr>
<th></th>
<th>$c_{wy}$</th>
<th>$c_{wy}$</th>
</tr>
</thead>
<tbody>
<tr>
<td>Interior</td>
<td>24</td>
<td>24</td>
</tr>
<tr>
<td>Edge</td>
<td>20</td>
<td>20</td>
</tr>
<tr>
<td>Corner</td>
<td>20</td>
<td>20</td>
</tr>
</tbody>
</table>

**Center-to-Center Span Lengths (ft)** - Enter the first 3 spans in order for additional spans to become available.

<table>
<thead>
<tr>
<th>A</th>
<th>B</th>
<th>C</th>
<th>D</th>
<th>E</th>
<th>F</th>
<th>G</th>
<th>H</th>
<th>I</th>
<th>J</th>
<th>K</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
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</tr>
</tbody>
</table>

**Notes**

- $c_{wy}$ - column dimension in the east-west direction in inches
- $c_{ws}$ - column dimension in the north-south direction in inches
- Using no more than three different column sizes usually results in the most economical structure.
### Dimensions / Void Parameters

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Total slab thickness</td>
<td>16 in.</td>
</tr>
<tr>
<td>Void type</td>
<td>Spherical</td>
</tr>
<tr>
<td>Void diameter</td>
<td>10 in.</td>
</tr>
<tr>
<td>Horizontal clear space</td>
<td>2 in.</td>
</tr>
<tr>
<td>Stiffness reduction factor</td>
<td>0.9</td>
</tr>
<tr>
<td>Shear reduction factor</td>
<td>0.3</td>
</tr>
<tr>
<td>Average void area in slab</td>
<td>70 %</td>
</tr>
</tbody>
</table>

### Notes
- **ACI 9.5.3:** This contains minimum slab thickness requirements for slabs without beams, which pertain to serviceability only.
- *Calculated minimum slab thickness is based on critical span(s).*
- *Input a slab thickness greater than or equal to that according to ACI 9.5.3.*
- Verify that the deflection of the slab, including the stiffness reduction factor, meets all applicable limiting criteria.
- The solid slab thickness above and below the voids is assumed to be the same; the sum of the solid slab thicknesses and the void height is equal to the total slab thickness. Also ensure that a total slab thickness is chosen that results in a solid slab thickness above and below the voids that can accommodate the required cover and reinforcing bar diameter for a given void depth.
- *Stiffness and shear reduction factors take into account the reduced stiffness and shear capacity of the slab due to the presence of the voids, respectively; consult manufacturers’ literature for appropriate values.*
- *The average void area in a slab is typically in the range of 70 to 80%.* For preliminary design, it is recommended to use a value of 70%.

### Material Quantities

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Top bar size</td>
<td>6 in.</td>
</tr>
<tr>
<td>Bottom bar size</td>
<td>7 in.</td>
</tr>
<tr>
<td>Additional reinforcement</td>
<td>5 psi</td>
</tr>
<tr>
<td>Width of solid concrete</td>
<td>2 ft.</td>
</tr>
</tbody>
</table>

### Notes
- An additional amount of reinforcement can be added to account for miscellaneous steel or flexural reinforcement. Leave field set to zero if you do not want additional reinforcement.
RC Concept

**VOIDED SLAB (CLICK FOR MORE INFO)**

<table>
<thead>
<tr>
<th>Column</th>
<th>C_W</th>
<th>C_S</th>
</tr>
</thead>
<tbody>
<tr>
<td>Interior</td>
<td>24</td>
<td>24</td>
</tr>
<tr>
<td>Edge</td>
<td>20</td>
<td>20</td>
</tr>
<tr>
<td>Corner</td>
<td>20</td>
<td>20</td>
</tr>
</tbody>
</table>

**Warnings Encountered:**
- Two-way shear requirements fail at an edge column for N-S design strip.*
- Two-way shear requirements fail at a corner column for N-S design strip.*
- Two-way shear requirements fail at an edge column for E-W design strip.*
- Two-way shear requirements fail at a corner column for E-W design strip.*
- *Increase column size, slab thickness, or concrete strength (in that order for economy); also consider using shear reinforcement (such as stud rails) or a flat slab system.

Building Footprint

Dimensions / Void Parameters

Notes:

- Minimum of 3 span lengths in direction measured center-to-center of columns starting with f_a-8 and
- Aspect ratios must be less than or equal to 2 for two-way systems.
- Successive center-to-center span lengths shall not differ by more than one-third (the longest span for two-way systems) or more than 20 percent for wide-module joint systems.
### VOIED SLAB

**Dimensions**
- Slab thickness:
  - Min. thickness (ACI 9.5.3): 18 in.
  - Void type: Spherical
  - Void diameter: 12 in.
  - Solid slab thickness above and below voids: 3.0 in.
  - Horizontal clear space between voids: 2 in.
  - Stiffness reduction factor: 0.9
  - Shear reduction factor: 0.5
  - Average void area in slab: 70%

**Notes**
- ACI 9.5.3 contains minimum slab thickness requirements for slabs without beams, which pertain to serviceability only.
- Calculated minimum slab thickness is based on critical span(s).
- Input a slab thickness greater than or equal to that according to ACI 9.5.3. Verify that the deflection of the slab including the stiffness reduction factor meets all applicable limiting criteria.
- The solid slab thickness above and below the voids is assumed to be the same; the sum of the solid slab thicknesses and the void height is equal to the total slab thickness. Also ensure that a total slab thickness is chosen that results in a solid slab thickness above and below the voids that can accommodate the required cover and reinforcing bar diameter for a given void depth.
- Stiffness and shear reduction factors take into account the reduced stiffness and shear capacity of the slab due to the presence of the voids, respectively; consult manufacturers literature for appropriate values.
- The average void area in a slab is typically in the range of 70 to 80%. For preliminary design, it is recommended to use a value of 70%.

**Factored Loads**
- Concrete displacement: 0.4 ft²/ft
- Dead load reduction: 53.8 psf
- Total factored load: 245.4 psf
- Total factored live load: 160.0 psf
- Total factored load: 409.4 psf
- Load check per the Direct Design Method of ACI 13.6: **OK**

**Notes**
- The concrete displacement corresponds to the amount of concrete that is displaced by the voids.
- The dead load reduction corresponds to the average reduction in slab dead load based on the average volume of voids in the slab.
- The average dead load of the slab takes into consideration the solid areas of the slab that are required around the columns and is determined by subtracting the percentage of the dead load reduction based on the assumed average void area in the slab from the weight of a solid slab based on the total assumed slab thickness.
- Maximum factored gravity loads are obtained using Eq. (9-2) in ACI 9.2.1 for dead loads (D) and floor live loads (L).
- If the load check is "NG", the Direct Design Method should not be used to analyze the system, and the results obtained from this analysis may not be realistic.
New Trends - Case Studies:

Miami Art Museum
UW LaBahn Arena
Harvey Mudd College
Miami Art Museum
Construction Progress Report

ACI 421 Session on Innovative Slab Design

VOIDED SLAB TECHNOLOGY
OPTIMIZING DESIGN AND IMPROVING CONSTRUCTABILITY

Michael A. Russillo, President
Cobiax USA Inc.
April 14, 2013
• Brief description of voided slab technology
• How the concept is implemented
• Sequence of construction
• Special features
• Concrete facts and project credits
• Questions?
Perez Art Museum Miami (PAMM)

• Opening: Fall 2013
• 4 levels: Interior 120,000sf; exterior 80,000sf
• 6 void sizes covering 80,000 sf
• Exposed Concrete w/ Architectural finishes
• Voided Slab Drivers:
  – Large spans with flat soffit
  – Thick slabs due to 4” and 6” rebates
  – 2” cover for slab reinforcing
  – Reduction of weight on piles
  – Silver LEED Certification
Basic idea of the voided slab technology

Eliminate concrete in the zones of a slab where from a static perspective there is no necessity for it. At the same time, optimize the slab’s thickness and building material volume.
Implementation of the idea

Hollow voids of recycled plastic, positioned in appropriate zones of flat plate slabs, contribute to dead load reduction without modifying flexural strength and load transfer to supports.
Mounting of cobiax in an in-situ slab

- Top static reinforcement
- **void cage modules**
- Bottom static reinforcement
- Formwork & bracing

The void cage modules take over the function of the wire chairs.
Cross section with voids (in-situ slab)

1st concreting stage: Anchorage layer to prevent buoyancy

2nd concreting stage: Remaining concrete after initial setting of 1st layer

- Top static reinforcement
- void cage modules
- Bottom static reinforcement
- Formwork & bracing
VOID CAGE STORAGE ON SITE
Sunrise on Biscayne Bay....

......More Voids to Install
Installing & Spacing Voids
450 mm voids
Clean-out before the concrete placement
Mockup
Exposed ceiling w/ 4” & 6” rebates
Upturned Beam
Sloped Auditorium Slab
EXPOSED BEAMS
Flying in Rebar for a Wall
CONSTRUCTION SEQUENCE
• GROSS AREA: 200,000 sf: 120,000 interior + 80,000 exterior
• TOTAL CONCRETE YARDAGE: 17,500 CY; 6,000 psi
  Supplier: Tarmac Concrete (Titan America)
• TOTAL REBAR TONNAGE: 3,000 tons
  Supplier: Gancedo Rebar Services
• VOIDS COVERED AREA: 80,000 sf
• 6 VOID SIZES: S-180, S-220, E-225, E-270, E-360 & E-450
• VOLUME OF CONCRETE DISPLACED: 935 CY
• WEIGHT REDUCTION ON PILES: 1,750 tons
Slab forms: 3/4” sacrificial deck/back-up (MDO plywood) to minimize deflection with 5’x10’ sheets of either Riga or Finn Form on top for form finish.

Wall forms of Finn Maxi-Ply on good side, backed with 3/4” plyform also to minimize deflection.

Rebates were formed with beveled 4x4 fir in 10’ lengths, faced with 5/8” Exactu.

Cover: 2” for slabs; 2-1/2” for beams and columns

Slag used to lighten w/ a blend of pea rock and regular rock. 5,000 psi specified / 6,000 psi delivered

Shrinkage reducing admixtures used in most of the concrete.
<table>
<thead>
<tr>
<th>Perez Art Museum Miami (PAMM)</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Project Director:</strong> Paratus Group, NY, NY</td>
</tr>
<tr>
<td><strong>Design Consultant:</strong> Herzog &amp; de Meuron, Basel, Switzerland</td>
</tr>
<tr>
<td><strong>Executive Architect:</strong> Handel Architects, NY, NY</td>
</tr>
<tr>
<td><strong>Structural Engineer &amp; M/E Engineer:</strong> Arup, NY, NY</td>
</tr>
<tr>
<td><strong>Construction Manager:</strong> John Moriarty &amp; Assoc., Florida</td>
</tr>
<tr>
<td><strong>Concrete Contractor:</strong> Baker Concrete / Reinforced Structures Inc., JV</td>
</tr>
<tr>
<td><strong>Reinforcing &amp; Cobiax Supply and Installation:</strong> Titon Builders Inc.</td>
</tr>
</tbody>
</table>
Perez Art Museum Miami (PAMM)
THANK YOU!

Inquiries: Michael A. Russillo, President
Cobiax USA Inc.
90 Pleasant Street
Dedham, MA 02026 
Tel: (781) 381-0111
mrussillo@cobiaxusa.com
Internet: www.cobiaxusa.com
Precast Voided Slabs

Dan Windorski, PE
GRAEF

Session sponsored by ACI 421
Voided Slab w/ precast stay in place form

- Voided Two-Way Flat Plate
- Use plastic spheres (bubbles) to displace concrete
- Designs and Behaves like monolithic concrete
- A merger of the best aspects of cast in place and precast concrete construction
Voided Slab w/ precast stay in place form
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Voided Slab w/ precast stay in place form
Voided Slab w/ precast stay in place form form

- Shear zone, no ball area, ~25% of span
- Shear capacity at bubbles equals 60% of shear capacity of a solid slab
- Site formed closure strip
Voided Slab w/ precast stay in place form
Voided Slab w/ precast stay in place form
UW LaBahn Arena
Madison WI
BIM Structural Model – LaBahn Arena
LaBahn Arena

- 21 inch Voided slab
  - Plaza Slab
    - Supports 3.5 feet of soil
    - Designed for fire truck loading
- 11,000 Square Feet
- Serves as roof of Badger hockey locker rooms
Why Voided Slab for UW LaBahn?

• Saved $2/SF
• Saved 174 CY of concrete
• Saved 3 days off of schedule
• Saved on shoring cost
• Saved structural depth
Harvey Mudd College
Teaching and Learning Building
Claremont, CA
BIM Structural Model – Harvey Mudd College

(courtesy of KPFF)
Harvey Mudd - TLC

- 4 –Story Education Building
- 80,000 square feet of Voided slab
- 9, 11, 13.5, 17.5 and 20 inch slab thicknesses used
- Located in high seismic zone
Why Voided slab for Harvey Mudd?

- Highly Visible Exposed Concrete Ceilings
- MEP Coordination/Pre-Installation
- Seismic Mass Reduced
- Long-term Deflection Considerations
- Saved 750 CY of Concrete
Watertown Regional Medical Center
East Addition

Watertown, WI
Watertown Regional Medical Center

- Emergency Dept & Women’s Health Addn
- 2-Story & 30,000 square feet
- Existing construction systems:
  - Concrete waffle slabs
  - Concrete pan joist
  - Precast concrete and steel beams
- System selection for healthcare facilities
  - Grid layout
  - Story height
Why Voided slab for WRMC?

• Flexible and larger column grid
• Thin structural system leads to higher headroom for MEP/medical systems.
• Material savings
• Increased construction speed by minimizing on-site labor
Summary

• Form work is virtually eliminated. Fewer lines of shoring.

• The finished underside of the panel can be left exposed and untreated.

• Overall building height is minimized reducing building façade.
Summary Cont.

- Reduced site labor, increased safety.
- Less onsite concrete, quicker pour time.
- Core holes are faster to drill.
- Building is more efficient, reduced carbon footprint, has potential for LEED credits.